Markets for Solid Waste Management in Arabic Countries

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Solid Waste Management (SWM) is a very challenging activity all over the world, especially with the rising world population, the growth in industrialisation and the expansion of urbanisation. Land scarcity and environmental and public health implications are raising serious concerns on the landfilling of solid waste as a disposal route. It is, therefore becoming exceedingly urgent, for the Arab region, to develop and implement disposal methods for MSW that is cost effective and environmentally sustainable.

There are many complex challenges facing the solid waste management in the Arab region, such as rapid population growth, lack of strategic planning, limited waste collection services, lack of proper disposal methods, the use of inappropriate technology and inadequate financing [3]. In order to create an effective SWM system in that region, these challenges must be addressed imminently.

It is worth mentioning that an effective SWM system is one which incorporates several activities and treatment methods as well as the use of a range of proven technologies as part of an integrated sustainable waste management solution (ISWM). The main objective of such SWM system should be the protection of public health and the environment.

In most of the cities in the Arab region, up to 50 % of the generated waste goes untreated to landfills or even merely dumpsites, and the collected waste is often mixed with industrial and medical waste during handling and disposal. The typical method of Municipal Solid Waste (MSW) disposal in most of the region is uncontrolled dumping, where it is poorly managed and lacks the most of the basic engineering and sanitary measures for the collection of methane and the treatment leachate. The inability of the existing waste management systems to cope with the growing waste generation rates has led to significant health and environmental problems in most Arab countries [1, 5]. The introduction and implementation of ISWM concept is urgently required for the region. Collection, composting, incineration of medical wastes and sanitary landfills are starting to be implemented, while reuse, recycling and energy recovery are still at the initial stages [5]. The investment required for different waste treatment plants, in the Arab region, for cities ranging between 500,000 to 1,000,000 inhabitants was estimated and summarized in Table 1.

Table 1: Estimated investment for waste treatment plants in the Arab region

Types of waste treatment plants	Capacity	Needed Investment
	Mg/a	million EUR
Waste tyre treatment plant	10,000	5 to 10
Waste Incineration Plants	200,000	100 to 150
Transfer Station	10,000	2 to 4
MBT – Mechanical Biological Treatment – Drying	100,000	10 to 15
MBT – Mechanical Biological Treatment – Composting	100,000	8 to 12
Landfill	350,000	40 to 50
Construction and demolition waste treatment plant	300,000	5 to 8
Hospital Waste disinfection/sterilization	500	1 to 1.5
Hazardous Waste Treatment Plants with incineration	10,000	40 to 50
Composting plant	20,000	2 to 4

The aim of this paper is to examine the treatment practices of MSW in the Arab region, in order to suggest possible alternatives treatment which could be adopted and implemented locally.

The performance of biological drying process of solid waste, by forced aerated windrow composting/stabilization, was investigated as part of a pilot scale experiments which was carried out in Tunisia (the stabilization process of the fine material is not discussed in this paper). Furthermore, the economic feasibility and financial risk of the project proposal is evaluated by carrying out a capacity analysis.

1. Pilot project in Beja city, Tunisia – Biodrying of mixed MSW

Due to a high proportion of food waste (> 50 %) in MSW in many developing countries, MSW has a high water content, which lowers the recovery rate of material and increases the operation cost of incineration treatment. [2, 4]. Nevertheless, some available processes could be used to treat mixed MSW which overcome these problems and improve the material and energy recovery rate from waste streams. For instance, composting and other bio-stabilization processes achieve complete degradation of the easily degradable organic matter and bio-drying process increases the waste calorific value by reducing its water content [2, 6, 8, 9].

A pilot project supported by the German Financial Cooperation via KfW (2014 to 2015), examined the transfer of the knowledge and technique of low cost mechanical biological pre-treatment for MSW to the conditions in Tunisia. Biodrying of mixed MSW was tested as part of this pilot project. The biodrying process, of the formed windrows was monitored by an automatic temperature control system, which continuously measured the temperature of the windrows. A forced aeration system was installed to the windrows, in order to introduce sufficient air into the waste at rates ensuring optimum conditions for biological activities. The setting of the aeration system, illustrated in Figure 1, was adjusted to maintain an average compost temperatures at around 40 ˚C to 70 ˚C. Turning of the waste, using a compost turning machine was conducted weekly to avoid poor air distribution and uneven composting of the waste in the windrow, and also to maintain a good porous structure throughout the entire composting period.

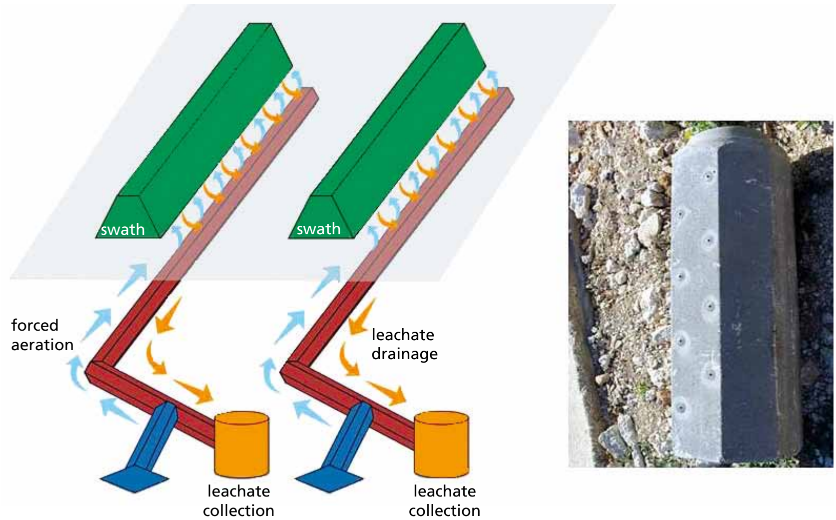


Figure 1: Ventilation system installed on the pilot site

Source: first interim unpublished-report of the project

In addition to accelerating evaporation of water, the forced aeration system helps to achieve optimum composting conditions and reduce the production of odorous substances. To further reduce the emission of odour to the environment and to protect the windrows from rain and heat from the sun, the windrows were covered with a semi-permeable membrane.

2. Screening of dried waste and mass balance

After three weeks of composting and drying, the waste can be screened efficiently into a coarse fraction with a high calorific value which can be used as a basis for the production of substitute fuel known as Refused Derived Fuel, (RDF), which can be used in cement kiln or combustion facilities. Mass balance of all trials during summer and winter seasons are illustrated in Figure 2.

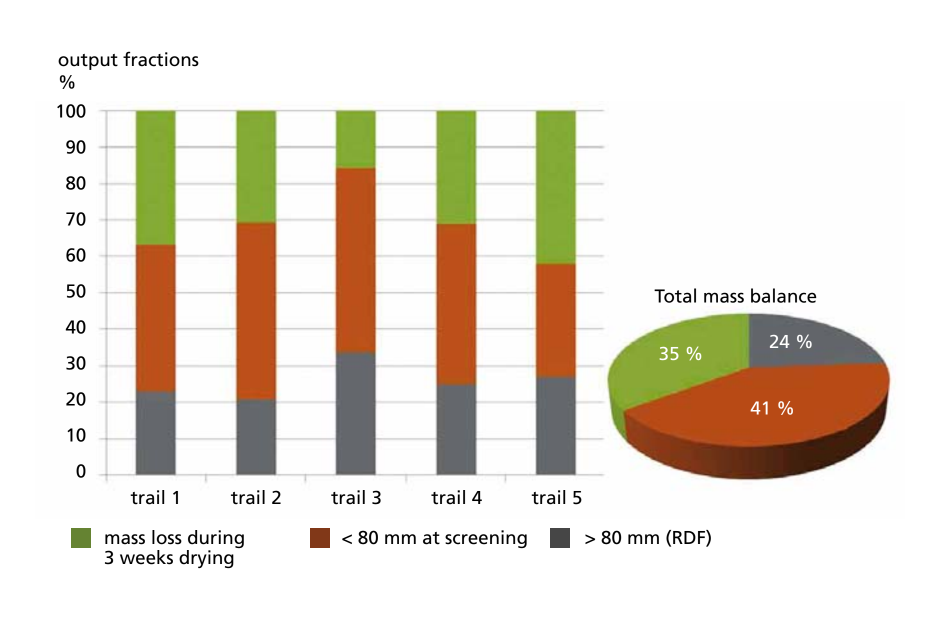


Figure 2: The percentage of fractions after screening at 80 mm for the total and each trial during the pilot project period (June 2014 to January 2015)

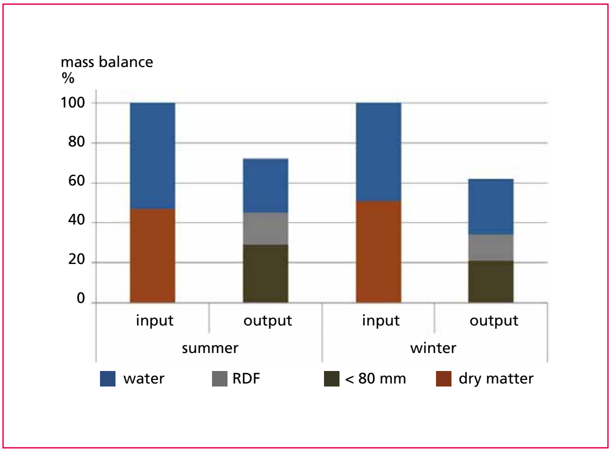


Figure 3:

The mass balance after the bio-drying process for the summer and winter trial

In total, the weight of MSW decreased by 29 % during summer and 35 % during winter, without considering the RDF utilization in these Figures of mass reduction. At completion of the biodrying process, the mass of waste was reduced by approximately 33 %, when the dry waste was directed to landfill without the recovery of material. In the case of RDF utilisation, from the dry waste, the mass of waste to be landfilled was reduced approximately by 60 % as can be seen in Figure 3. Furthermore, the disposal of the dried waste, at the end of the biodrying process, at the landfill would not produce leachate, given that the landfill is carefully covered and protected from rainfall.

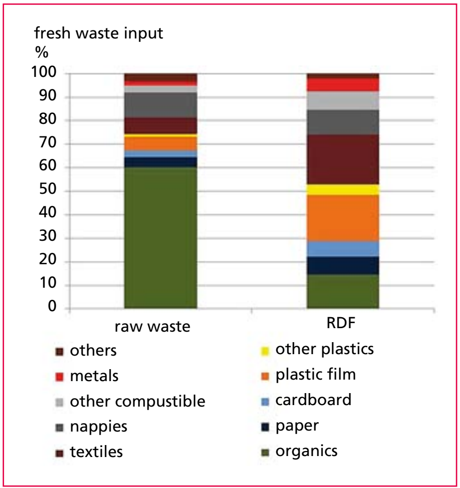


Figure 4: The average characteristics of fresh waste (input) and the coarse fraction > 80 mm after the end of the biodrying process (3 weeks)

3. Characteristics of produced RDF

Analysing the coarse fraction (> 80 mm) after the end of the biodrying process was conducted for each trial during both seasons. As an average of both seasons, refer to Figure 4, the major components of RDF are textile (21.2 %), plastics films (19.7 %), nappies (10.5 %) and cardboard (6.4 %). Others combustible materials present include paper (15.4 %), other plastics (4.5 %) and organics (14.5 %). There is still some organics in the coarse fraction, but this can be reduced further by optimisation measures. Impurities in the RDF contain non-combustible materials namely, metals (5.5 %) and glass and inert material (2 %)

4. Chemical properties of the RDF

The results of the basic chemical properties of RDF-base material are presented in Table 2 which includes the calorific value, other important fuel properties such as the moisture content, the chlorine content and the ash content.

Moisture content shows great variability, ranging from 25 % to 50 %. The biodrying process reduced the moisture content of waste, and in turn increased the waste's calorific value by about 20 %, from 16.79 (summer value) and 15.56 MJ/kg (winter value) for the untreated waste to 20.61 (summer value) and 18.87 56 MJ/kg (winter value) for the biodried material, which makes it appropriate as a fuel. The ash content of the RDF produced in Beja appears to be at the high range, between 20 % to 31 %. Chlorine is also a limiting factor for RDF quality, not only for ecological reason but also for technical reason.

Table 2: The basic chemical features of RDF produced in the study area

parameter			summer trail			winter trail	total
			1	2	3	4	
DM input	%		47	44	54	47	48
LHV input	MJ/kg	wet	16.04	16.79	17.94	15.56	16.24
DM output/RDF	%		75	69	50	67	66
LHV output/RDF	MJ/kg	wet	18.87	20.61	19.96	18.87	19.58
Ash output/RDF	%		31.9	17.6	20.3	23.8	24
Chlorine output/RDF	% w/w		0.84	0.66	1.30	0.94	0.94
Heavy metals output/RDF	mg/kg	Cd	0.76	0.45	4.18	0.62	1.21
		Cr	89	74.7	96	142	114.28
		Ni	71.1	34.9	45.6	70.2	60.37
		Hg	0.45	0.34	0.27	0.55	0.45
		Zn	262	141	140	229	205.00
		As	3.5	2.3	4.5	3	3.22

Chlorine content ranges between 0.66 to 1.30 % w/w. The results on heavy metal concentrations in the RDF samples, as per Table 2, showed high concentrations of heavy metals. This could be explained by the high content of organic material and fine particles in the RDF produced, which may have high heavy metal.

A good quality RDF should have high calorific value and low concentration of toxic chemicals especially for heavy metals and chlorine. Due to the different point of view of RDF producers, potential RDF customers and the respective authorities, suggested RDF quality varies from one to another group [7]. It becomes clear from the results that the RDF produced in Beja is of a high calorific value, low moisture and acceptable chlorine and heavy metals content.

5. Proposed RDF facility for the Arab region

Two strategies have been considered for RDF production facility.

The first is based on the recovery of RDF and recyclables after the biodrying of raw waste, while in the second strategy the raw waste is processed into RDF, recyclable material are recovered and the fine fraction is further stabilized before landfilling.

The main objectives of the chosen options are:

- Recovering recyclable material,
- Diverting material from landfill,
- Relevant factors: recovery efficiency, costs and time needed for treatment.

The assumptions made for the following strategies are based on the available results which were obtained during the summer trial from the pilot project in Beja.

5.1. Biological drying of mixed MSW with RDF production and recyclables recovery

The concept of this strategy is proposed for facilities with a capacity of (Option 1. with 50,000 Mg/a and Option 2. with 100,000 Mg/a). The waste will be subjected to composting (biodrying) without adding any water for 2 to 4 weeks. At completion of the drying process the waste would be screened efficiently into a coarse fraction with high calorific value, which can be used as a basis for the production of substitute fuel (RDF), Figure 5.

Based on the results obtained for the pilot project in Beja, the mass of input waste will be reduced by approx. 60 %. This means that only 40 % of the input material will be sent to the landfill and 60 % will be diverted from landfill.

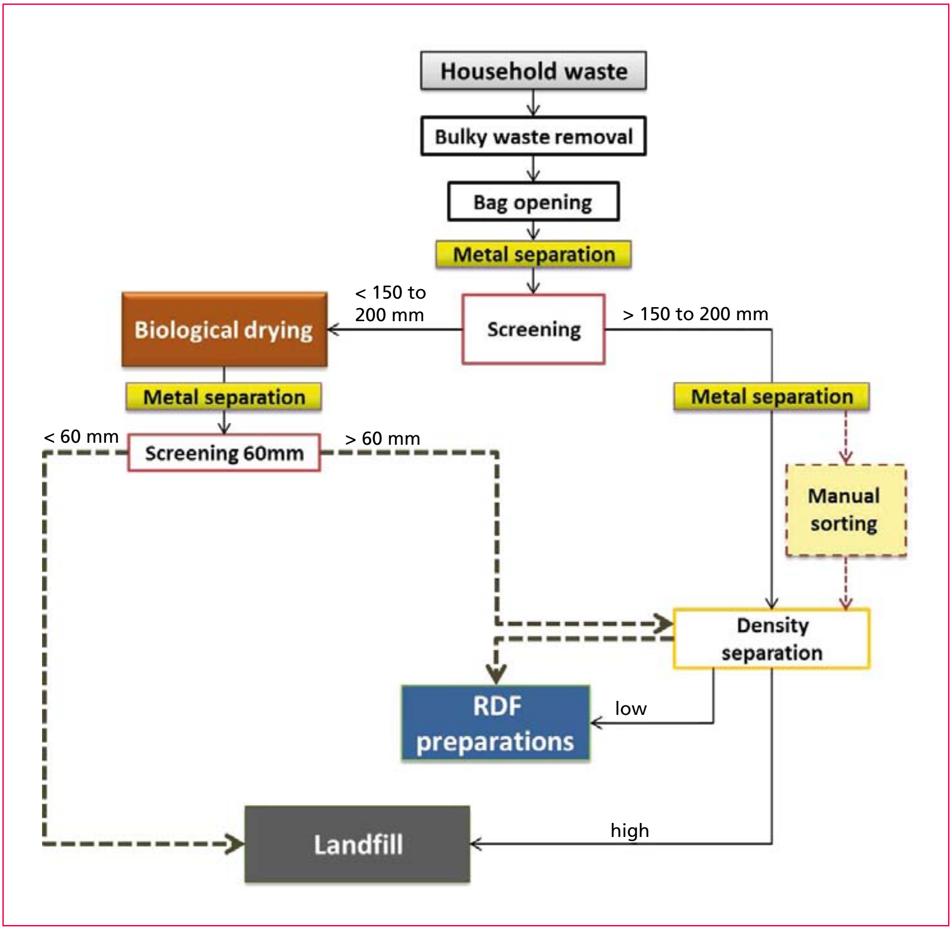


Figure 5: Strategy 2, biological drying, RDF production and recyclable material recovery

5.2. Biological drying of mixed MSW with RDF and metal recovery and stabilization of organic material before landfilling

The concept of this strategy is the same as the concept of the previous strategy, except that at the end of the drying process the fines fraction, after screening would go through further composting/stabilization for further mass reduction. The composting period is about 6 to 8 weeks. Refer to Figure 6. Two options will be studied for this strategy:

Option 3. Biodrying with RDF, recyclables recovery and stabilized material for landfilling.

Option 4. Biodrying with RDF, recyclables recovery, compost-like output (CLO) and inert material for landfilling.

Based on the stabilization results obtained from the pilot project in Beja, the mass of the stabilised portion will be reduced by approximately 87 %. This means that only 13 % of the waste input will be sent to the landfill ,while the rest is recovered as RDF fuel, recyclable material (metals) and compost like product with moisture content loss as a result of the biodrying and stabilization process.

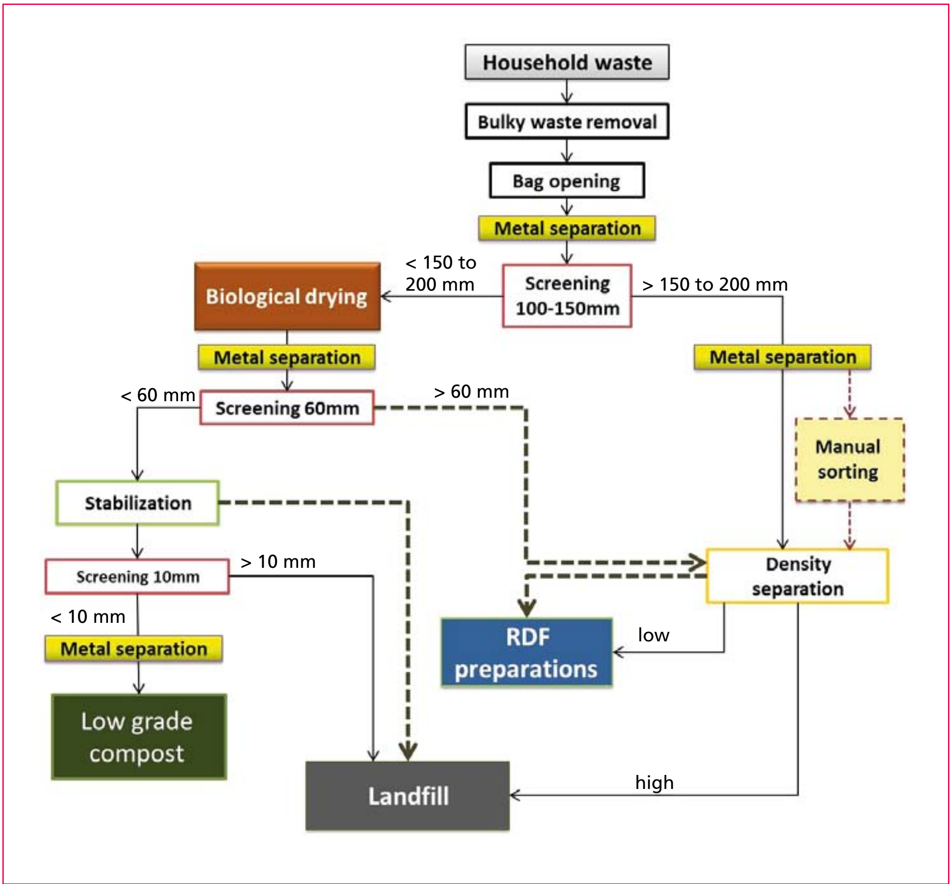


Figure 6: Strategy 3, biological drying, RDF and stabilized material production and recyclable material recovery

6. Economic feasibility analysis

Based on the availability of the RDF and its composition, it is useful to estimate the costs related to its production and management. The cost of each plant includes two main components. Total capital investment, and operation and maintenance cost. Total capital investment includes the costs of the main machineries and equipment, their installation, engineering, construction and supervision, and the cost of capital or interest payment. Meanwhile, operation and maintenance cost is generally divided into maintenance, operating labour, supervision, plant overheads, laboratory expenses, raw materials/consumables, utilities and transportation. Revenue is generated, mainly from the sale of produced RDF, recycled materials, as well as from MSW gate fee. It was assumed that the plant will work for 4,000 hour per year to treat the required quantity of waste, which means that the plant will operate 2 shifts per day, each shift is 8 hours. Cost analysis has been performed for different facilities and the assumptions were made, shown in Table 3 for the different parameter involved in the cost calculation to suite the region situation.

parameter	**value**	**unit**
Net equity percentage	30	%
Useful economic life	15	years
Interest (inflation adjusted)	5	% p.a.
Insurance, Revisions	2	% p.a.
Expenses		
removal costs for residues and transportation	10	EUR/Mg
maintenance costs	100	EUR/h
Electricity consumption costs	80	EUR/MWh
Personnel costs (1 man)	12,000	EUR/a
number of necessary persons	40	
effective	480,000	EUR/a
Revenues		
Gate fee	20	EUR/Mg
Sale of RDF	30	EUR/MWh
Sale of recyclables	50	EUR/Mg
Sale of compost like output	10	EUR/Mg

Table 3:

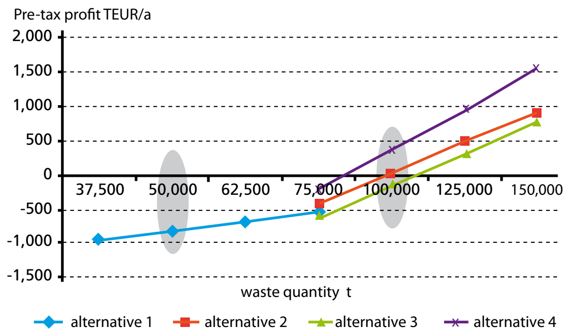
Assumption of different parameters for the cost calculation

As shown in Table 4, the cost of capital investment starts from 38 % up to 50 % of the total costs. The high percentage of the investment cost makes it hard to gain enough revenue of the sale of RDF and recycling material produced. For treatment cost per tonne more than 30 EUR/t there was no profit. Therefore, the cost of treatment per ton should be less than that.

Table 4: The total capital investment, operation and maintenance cost and revenues for the four suggested alternatives

Alternative	1	2	3	4	unit
Capital Investment	8	12	14	14	MioEUR
waste quantity	50,000	100,000	100,000	100,000	t/a
Annual costs (operation and maintenance)					
Net debt service (Capital investment)	859,517	1,289,275	1,504,154	1,504,154	EUR/a
Personnel costs	480,000	480,000	480,000	480,000	EUR/a
Maintenance costs (abs)	400,000	400,000	400,000	400,000	EUR/a
Electricity consumption costs	320,000	320,000	320,000	320,000	EUR/a
Removal of residues	197,938	395,875	342,400	39,375	EUR/a
Sum costs	2,257,454	2,885,150	3,046,554	2,743,529	EUR/a
Operation cost	1,397,938	1,595,875	1,542,400	1,239,375	EUR/a
investment/total cost	38 %	45 %	49 %	55 %	
Operation cost/t	28	16	15	12	EUR/t
total cost/t	45	29	30	27	EUR/t
Revenues					
Waste acceptation	1,000,000	2,000,000	2,000,000	2,000,000	EUR/a
Sale of recyclable material	136,563	273,125	273,125	273,125	EUR/a
Sale of RDF	310,500	621,000	621,000	621,000	EUR/a
Sale of CLO	0	0	0	212,118	EUR/a
Sum earnings	1,447,063	2,894,125	2,894,125	3,106,243	EUR/a
Pre-tax profit	-810,392	8,975	-152,429	362,713	EUR/a

waste quantity			37,500	50,000	62,500	75,000	100,000	125,000	150,000	t
pre-tax profit TEUR/a	alternative 1	50,000 t/a drying and RDF production	-943	-810	-678	-546				TEUR/a
	alternative 2	100,000 t/a drying and RDF production				-436	9	454	898	TEUR/a
	alternative 3	100,000 t/a with stabilization				-610	-152	306	763	TEUR/a
	alternative 4	100,000 t/a with compost				-224	363	949	1,536	TEUR/a



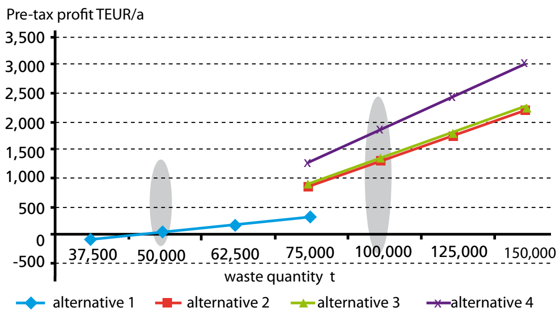
Parameter		
Capital investment	8, 12 ,14	Mio EUR
Net equity	30	%
Useful economic life	15	years
Interest (inflation adjusted)	5	% p.a.
Costs		
Effective personnel costs	480,000	EUR/a
Maintenance	100	EUR/ Op hour
Removal of residues	10	EUR/Mg
Electricity consumption	80	EUR/MWh
Earnings		
– Waste acception fee	20	EUR/Mg
RDF sale	30	EUR/Mg
Sale of recyclable material	50	EUR/Mg
Sale of compost	10	EUR/Mg

Figure 7: Revenue from the four suggested alternatives considering the capital cost is covered by private sector

Moreover, total capital cost price (Net debt service) and waste quantity treated have been studied in the analysis of the proposed facilities as a case study. Figure 7 shows the effect of change in these parameters upon investment return. From the cost analysis, it was clear that larger sized plant and machinery are required. Therefore, high capital investment is needed to set up a RDF plant, however, return on investment is not guaranteed to treat the designed waste quantity for all cases.

The most challenging parameter appears to be the capital cost, to overcome this obstacle, the involvement of the local municipalities and governments is recommended so that to take responsibilities of providing the initial capital cost. The public sector has better opportunities to gain grants and loans for such project than the private sector. As a result the rate of return will increase and better economic performance can be achieved and sustained for all alternatives which will cover the operational and maintenance cost to ensure sustained operation of the facilities, as shown in Figure 8.

waste quantity			37,500	50,000	62,500	75,000	100,000	125,000	150,000	t
pre-tax profit TEUR/a	alternative 1	50,000 t/a drying and RDF production	-83	49	181	314				TEUR/a
	alternative 2	100,000 t/a drying and RDF production				854	1,298	1,743	2,187	TEUR/a
	alternative 3	100,000 t/a with stabilization				894	1,352	1,810	2,268	TEUR/a
	alternative 4	100,000 t/a with compost				1,280	1,867	2,454	3,040	TEUR/a



Parameter		
Capital investment	14	Mio EUR
Net equity	30	%
Useful economic life	15	years
Interest (inflation adjusted)	5	% p.a.
Costs		
Effective personnel costs	480,000	EUR/a
Maintenance	100	EUR/ Op hour
Removal of residues	10	EUR/Mg
Electricity consumption	80	EUR/MWh
Earnings		
– Waste acception fee	20	EUR/Mg
RDF sale	30	EUR/Mg
Sale of recyclable material	50	EUR/Mg
Sale of compost	10	EUR/Mg

Figure 8: Revenue from the four suggested alternatives considering the capital cost is covered by public sector

Furthermore, it is important to point out that other benefits could be achieved in terms of improved quality of life, reduced health damage, as well as environmental benefits associated with reduced pollution and preserved landfill.

7. Conclusion

A good alternative for the region is the waste to energy concept where mixed MSW is converted to RDF. This alternative mainly contributes to the reduction of the moisture content of the waste while increasing the calorific value of the resulting product. It further decreases the production of leachate of landfilled material, if no further stabilization of organic material is applied. It becomes clear from the results that the RDF produced in Beja is of high calorific value, low moisture and acceptable chlorine content compared to the RDF's produced in other countries. The success of SWM is based on the organization and cooperation between different involved parties (politics, private sector, consultant companies and public sector). Overall, every possible solution will still need a landfill as inert or stabilized material. The selection of the appropriate solution for MSW must be based on many factors, such as the availability of land for disposal, market for recyclable material and the need for energy production, and taking into account economic and social aspects, with particular attention to environmental issues.

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